Aircrew Cosmic Radiation Exposure

A PPARC Sponsored Collaboration

The Effect of Forbush Decreases and Solar Particle Events on the Cosmic Radiation Dose Received on Commercial Flights: Preliminary Results

R. H. A. Iles[1], G. C. Taylor[2], J. B. L. Jones[3], D. J. Thomas[2], R. Hunter[4], R. D. Bentley[1], L. K. Harra[1], A. J. Coates[1]

[1] Mullard Space Science Laboratory, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK. (rhi@mssl.ucl.ac.uk)

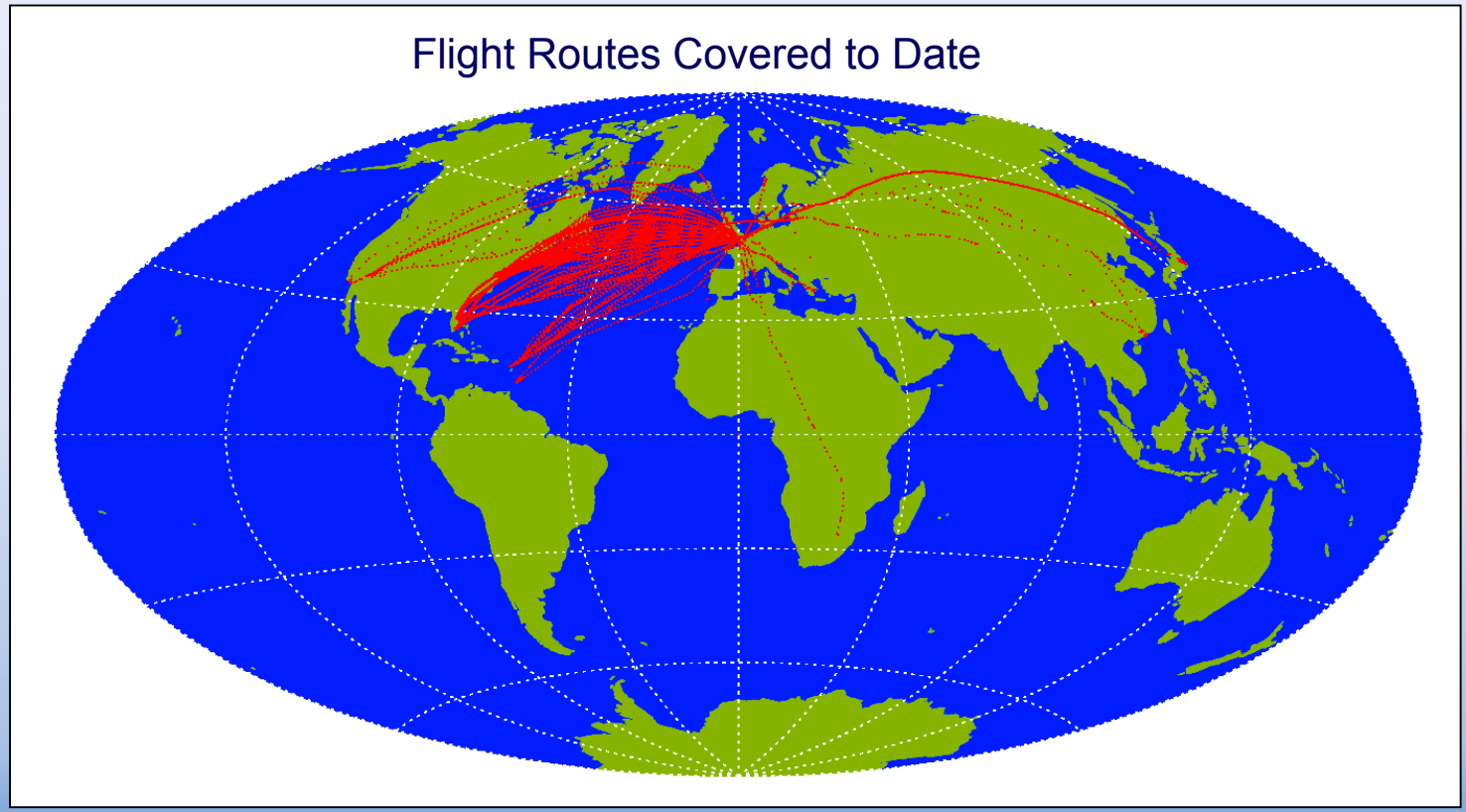
[2] National Physical Laboratory, Queens Road, Teddington, Middlesex, TW11 0LW, UK.

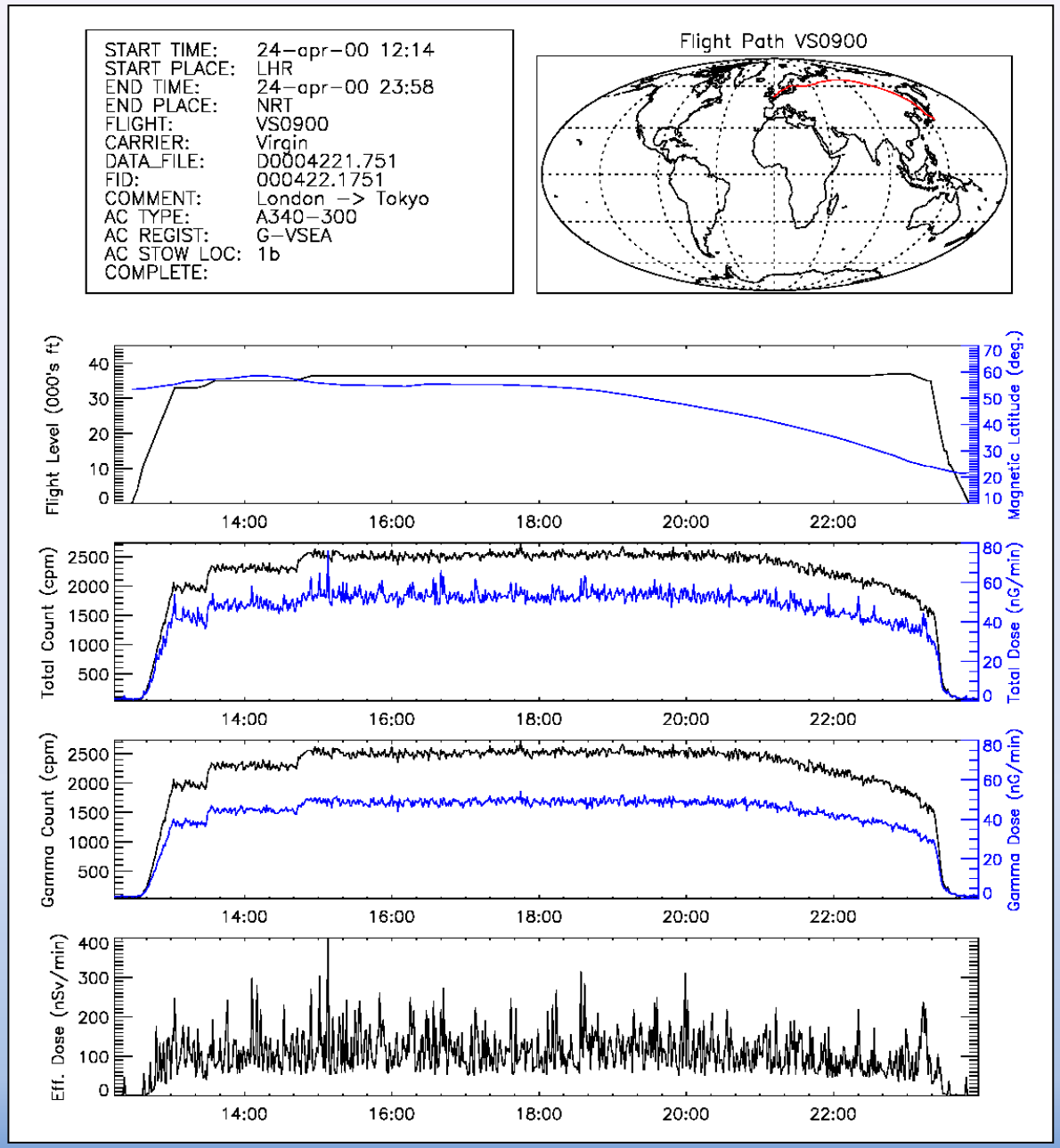
[3] Virgin Atlantic Airways Ltd, Manor Royal, Crawley, West Sussex, RH10 2NU, UK.

[4] Civil Aviation Authority, Aviation House, Gatwick Airport South, Gatwick, West Sussex, RH6 0YR, UK.

The project's aims include:

- Validation of radiation dose models currently used by airlines to assess aircrew exposure
- Evaluate variations in the cosmic radiation (CR) levels due to solar activity, in particular those effects not accounted for by the existing models
- To date measurements have been recorded on over 500 flights, with dose information being stored every minute





Sample Flight Data Summary

Measurements are made with a Tissue Equivalent Proportional Counter (TEPC)

Outputs:

- Total Counts (cpm)
- Gamma Counts (cpm)
- Total Dose (nGrays/min)
- Gamma Dose (nGrays/min)
- Effective Dose (nSv/min)

For the purpose of this preliminary investigation we have used Total Dose rather than Effective Dose because of the reduced statistical variations

Instrument calibration require that the TEPC measurements presented here be divided by a factor of 1.3

Data Analysis Methodology

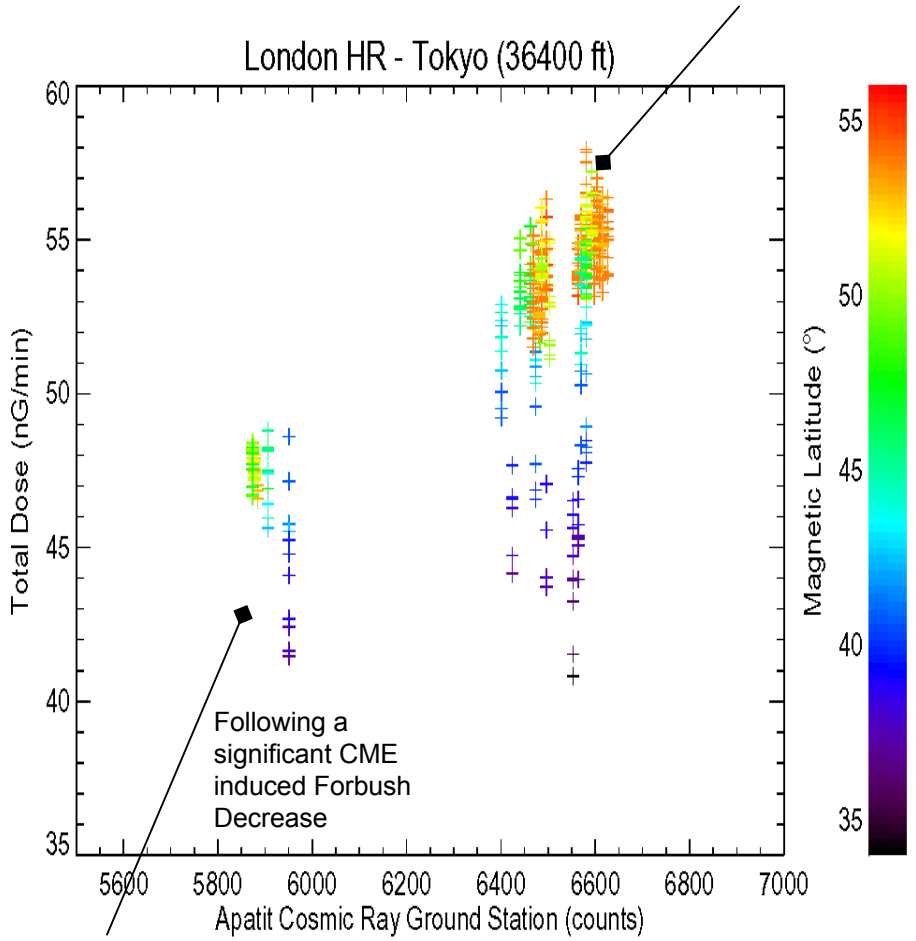
- Divided the World into voxels of 1º magnetic latitude by 1 º longitude
- Split each flight first into flight levels (+/- 100m) and then binned the data from each flight level into the pre-specified voxels

Investigating the Effect of Forbush Decreases

- Selected a well defined consistent flight route; in this case the London-Tokyo route
- Used coincident measurements made at cosmic ray ground stations as a measure of the Galactic Cosmic Ray (GCR) intensity
- Used TEPC measurements of Total Dose (nGrays/min) as a measure of the effect on exposure rate at altitude

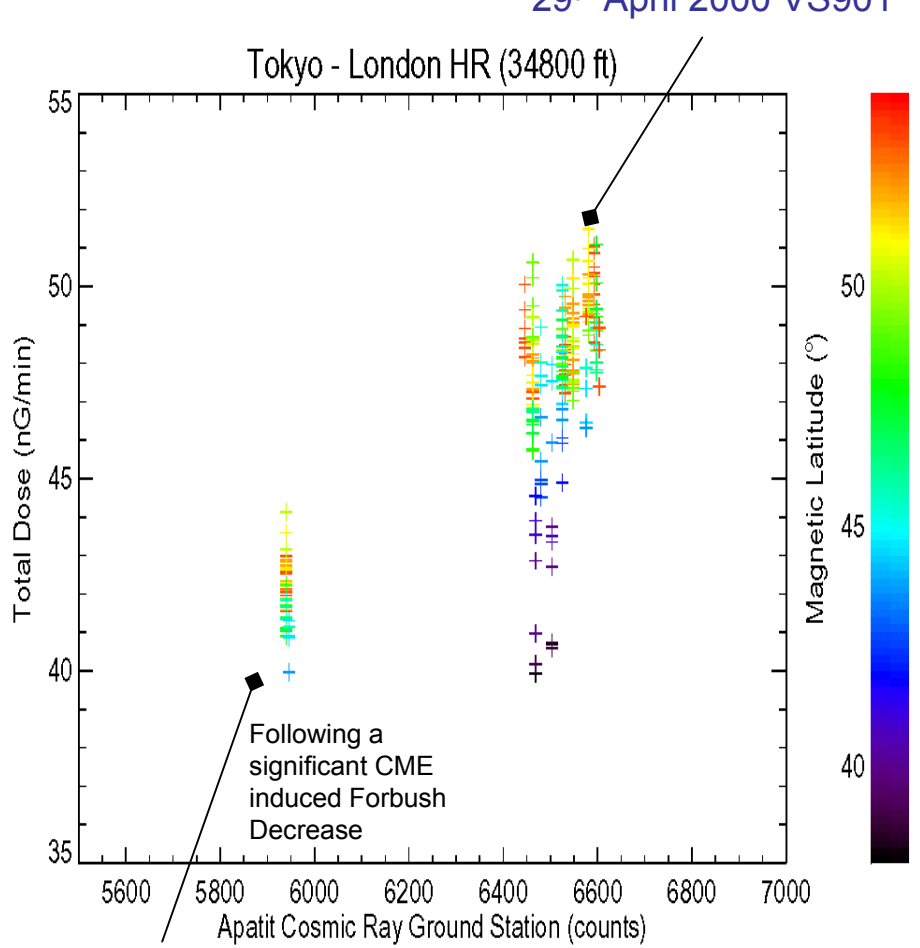
The effect of changing GCR intensity on the Total Dose during 5 flights from London to Tokyo (LH plot) and the return flights (RH plot)

28th April 2000 VS900



20th July 2000 VS900

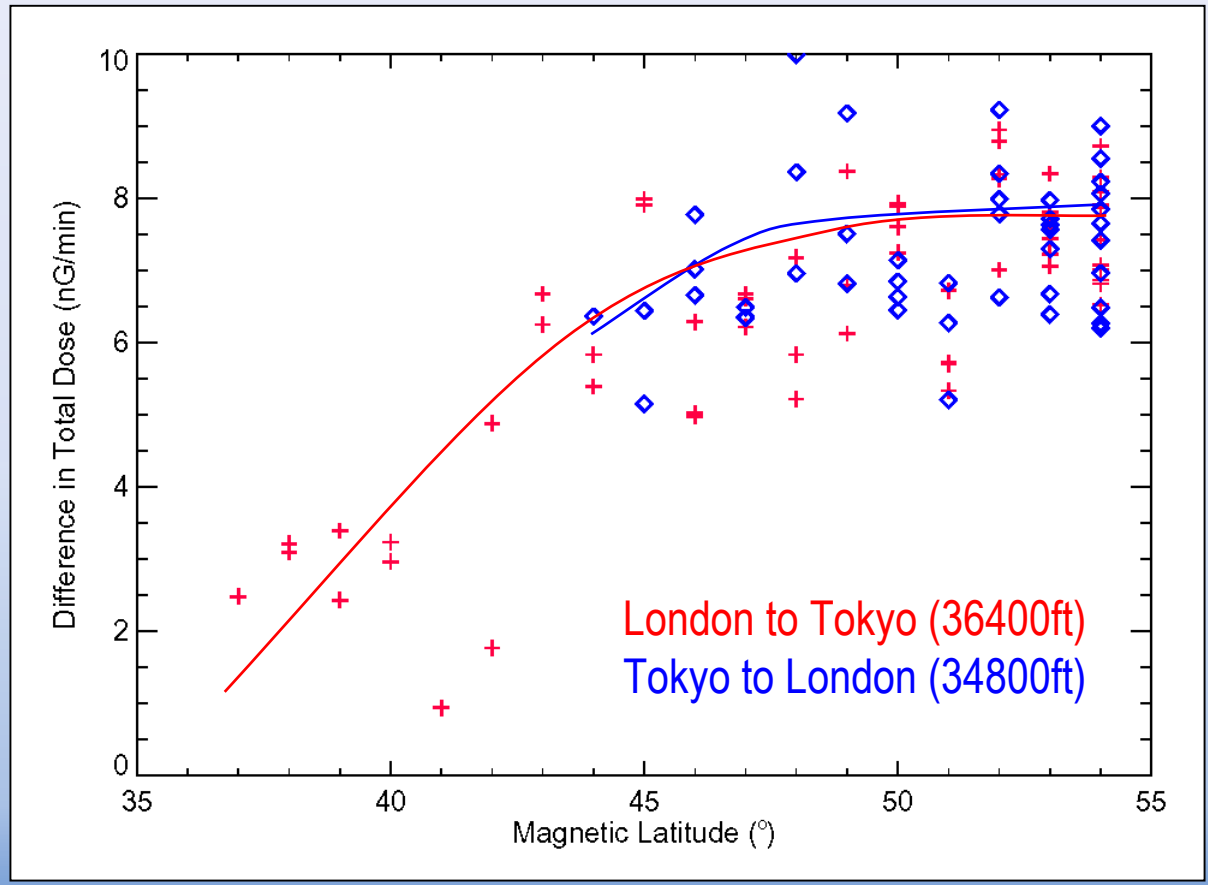
29th April 2000 VS901



21th July 2000 VS901

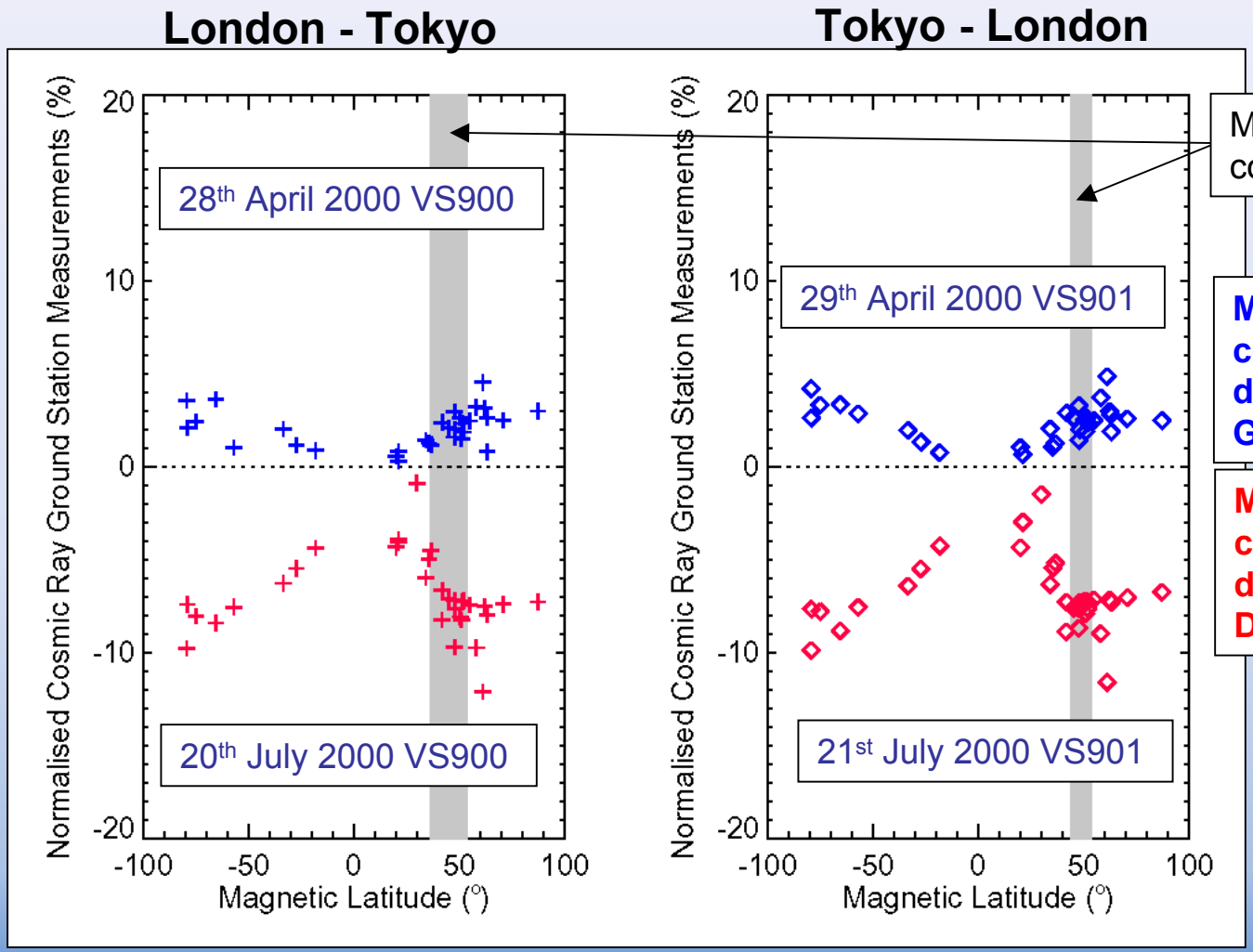
Latitude Dependence of a Forbush Decrease - The difference in the Total Dose (TD) between two flights caused by a Forbush Decrease as a function of magnetic latitude

- The difference in TD tends towards zero for magnetic latitudes < 35º ≡ Cut-off Rigidity 6 – 7 GeV
- Implying the Forbush Decrease does not significantly influence GCRs > 7 GeV



The variation in GCR intensity seen from the World-wide network of Cosmic Ray Ground Station Neutron Monitors

- Measurements were made coincident with the flights and normalised to the yearly average.
- Determined the difference in ground level GCR intensity for each pair of flights



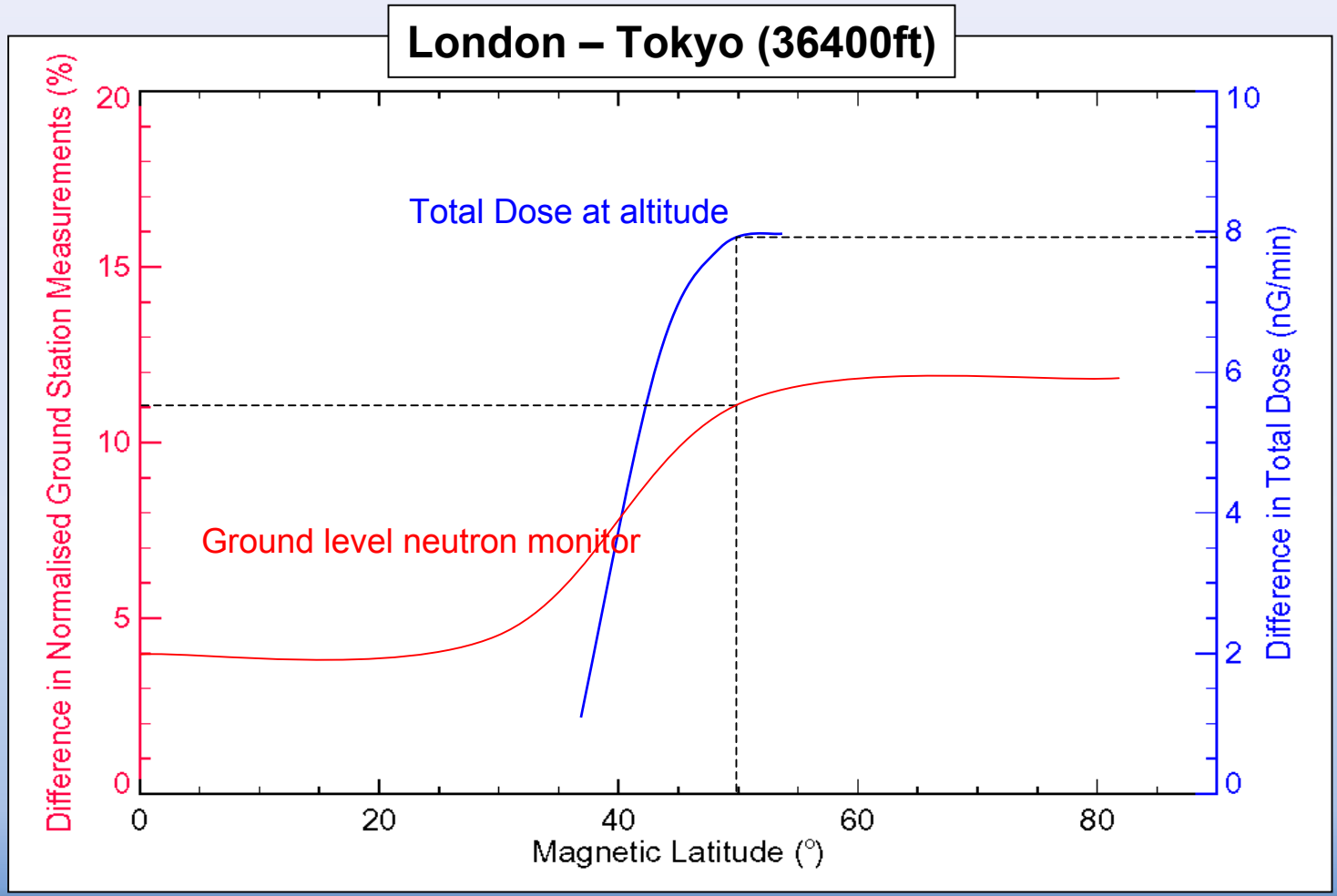
Magnetic Latitude range covered by the flights

Measurements made coincident with flights during normal or raised GCR intensity

Measurements made coincident with flights during a Forbush Decrease

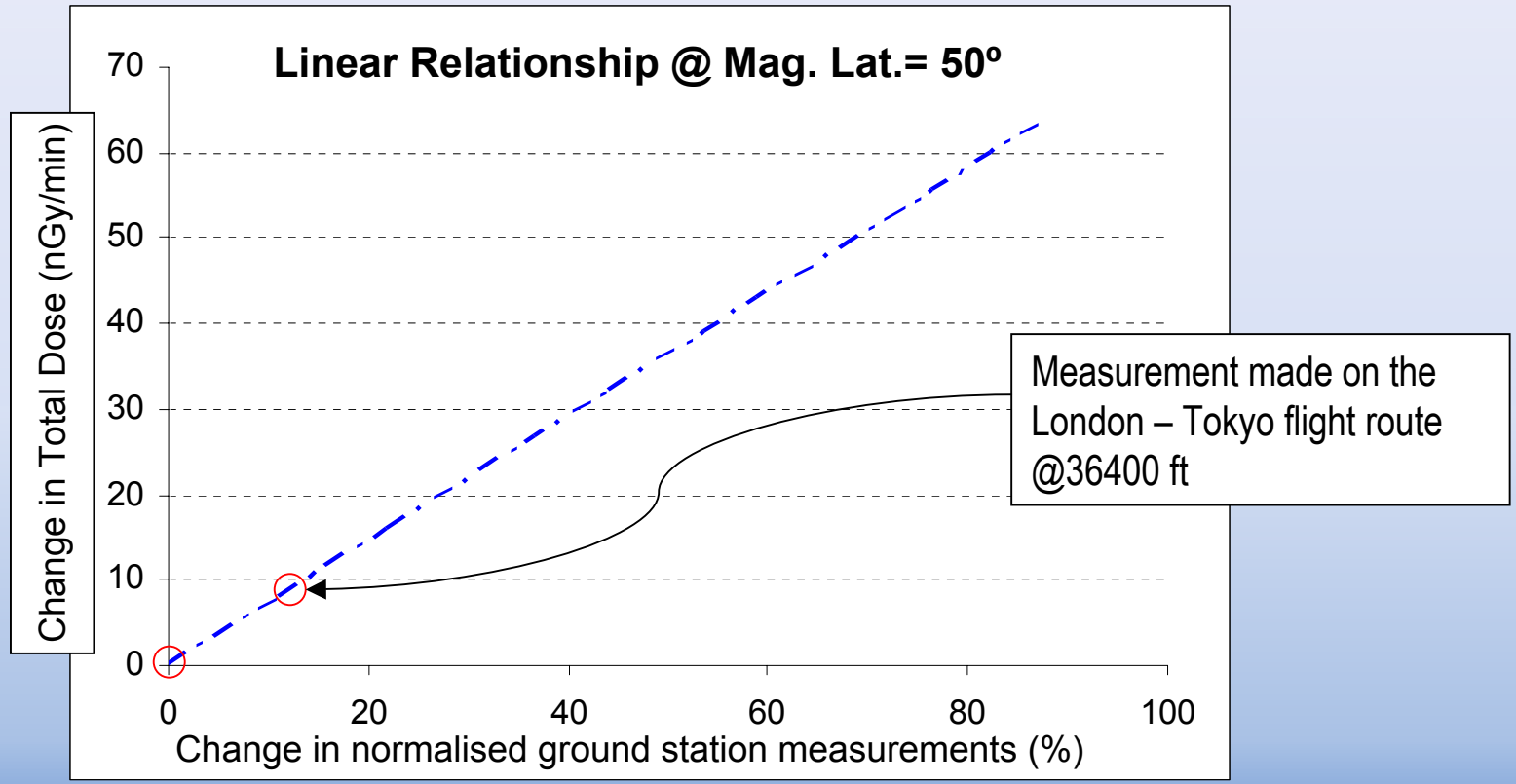
Use of ground level GCR measurements as a measure of the variation in Total Dose @ 36400 ft

- Results for London to Tokyo flight route
- E.g. for a magnetic latitude of 50º there is an ~11% change in the GCR intensity at ground level which corresponds to a change in Total Dose of ~8 nGy/min at 36400ft.



Assumption:

- For a specific magnetic latitude, assume a linear relationship between the measured variation in Total Dose @ 36400 ft with the coincident change in the ground level GCR intensity
- Such that, for a magnetic latitude = 50º, the Total Dose varies at a rate of 0.7nG/min/%.



Results from CARI-6M

- Initial results from CARI-6M suggests that the response remains close to linear for up to a 10% variation in GCR levels measured at ground level

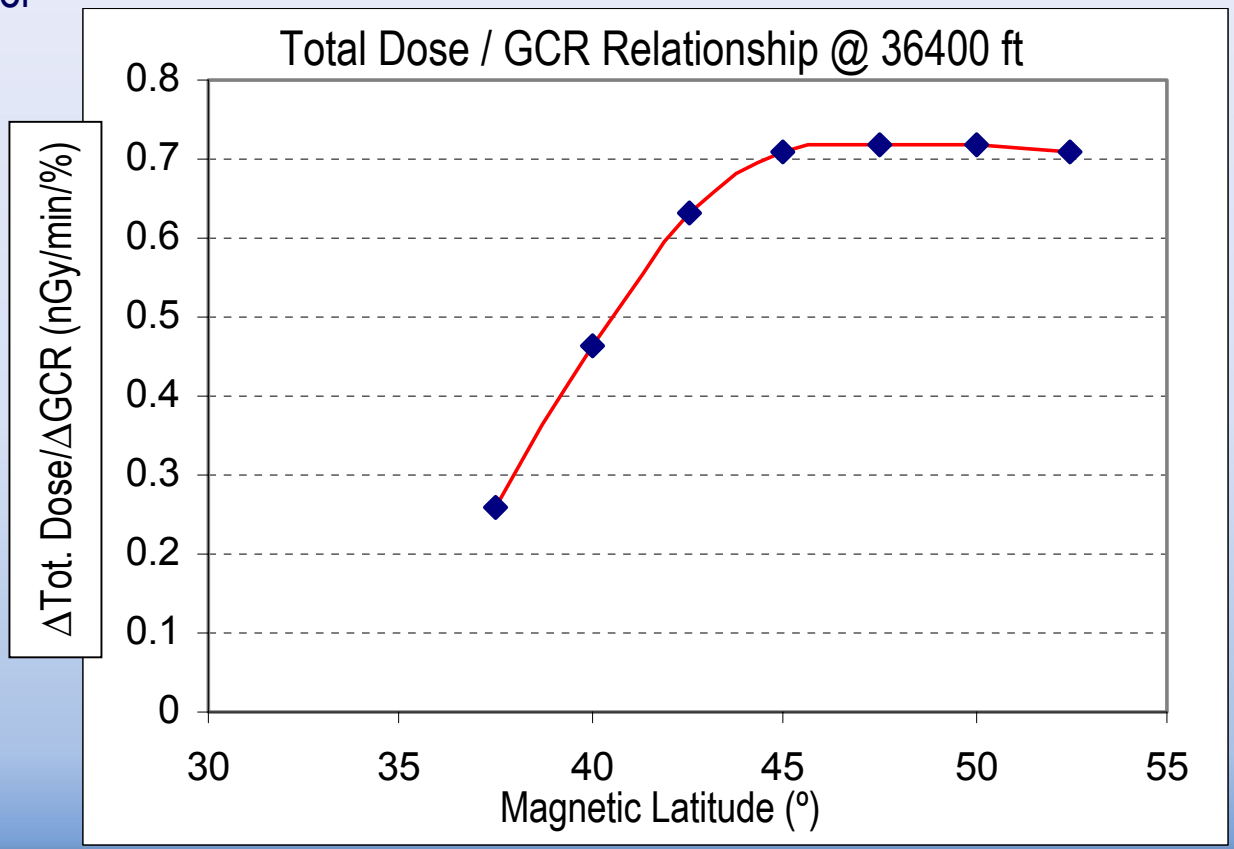
Results from CARI-6M

Date	Variation @ CLIMAX (%)	Heliocentric Potential (MV)	Eff. Dose (uSv/hour)	dEff. Dose /dCLIMAX (nSv/hour/%)
01/2000	4.97	837	4.99	
10/2000	1.43	940	4.83	
Difference:	3.54	103	0.16	**45.2**
01/2000	4.97	837	4.99	
06/2000	-2.43	1077	4.64	
Difference:	7.40	240	0.35	**47.3**
01/2000	4.97	837	4.99	
07/2000	-5.10	1087	4.49	
Difference:	10.07	250	0.50	**46.7**

Data assumes an altitude of 36400 feet at Lat 39.0 N and 106.0 W (≡ location of CLIMAX)

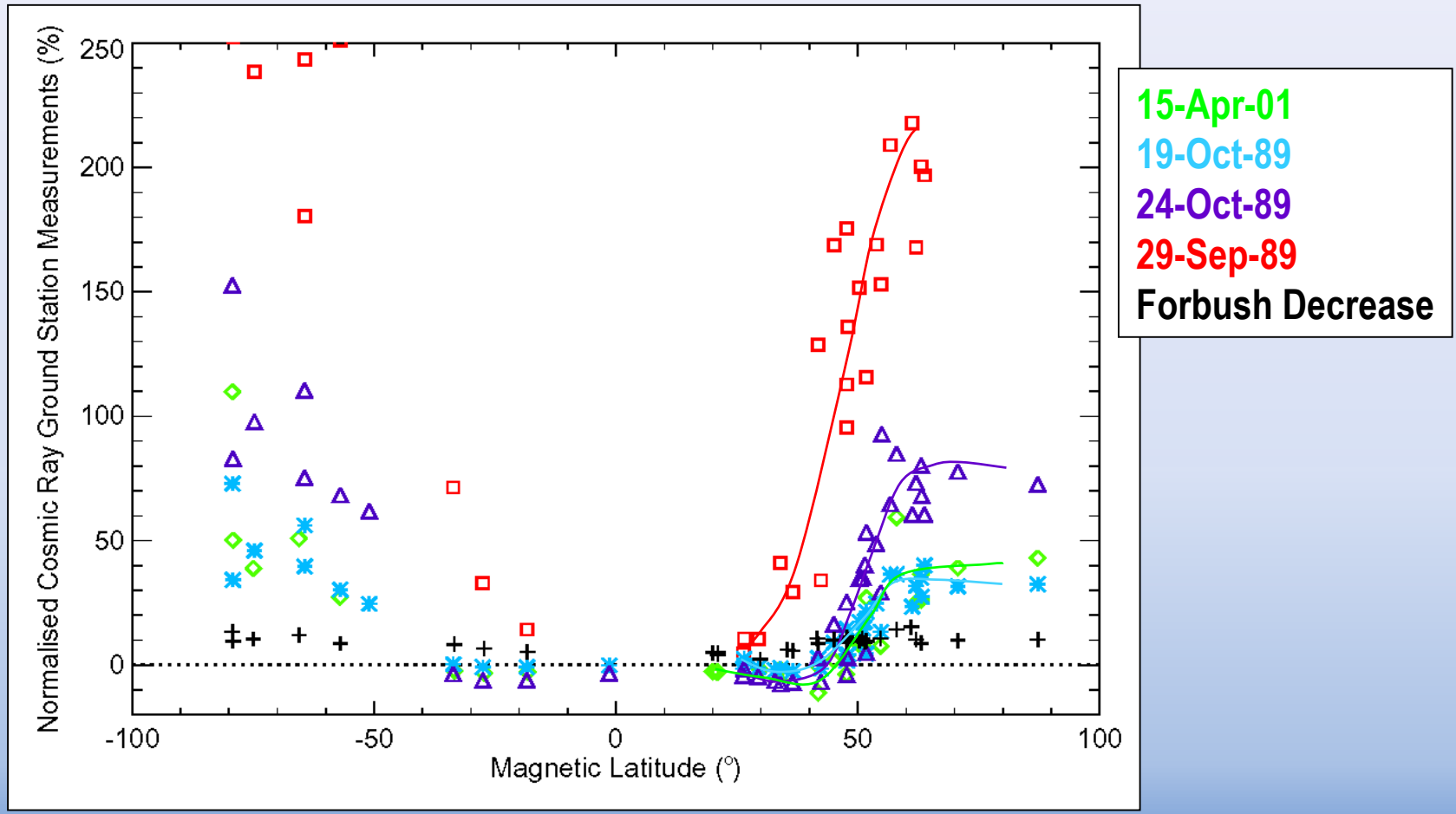
Total Dose / GCR Relationship as a Function of Magnetic Latitude

- Assuming a linear relationship and using the results from the London to Tokyo flights we can plot the variation of Total Dose with ground level GCR intensity as a function of magnetic latitude
- Using this result it is possible to determine variations in the Total Dose (@36400ft) as a function of magnetic latitude for any observed variation in the GCR intensity measured at ground level



Next Steps:

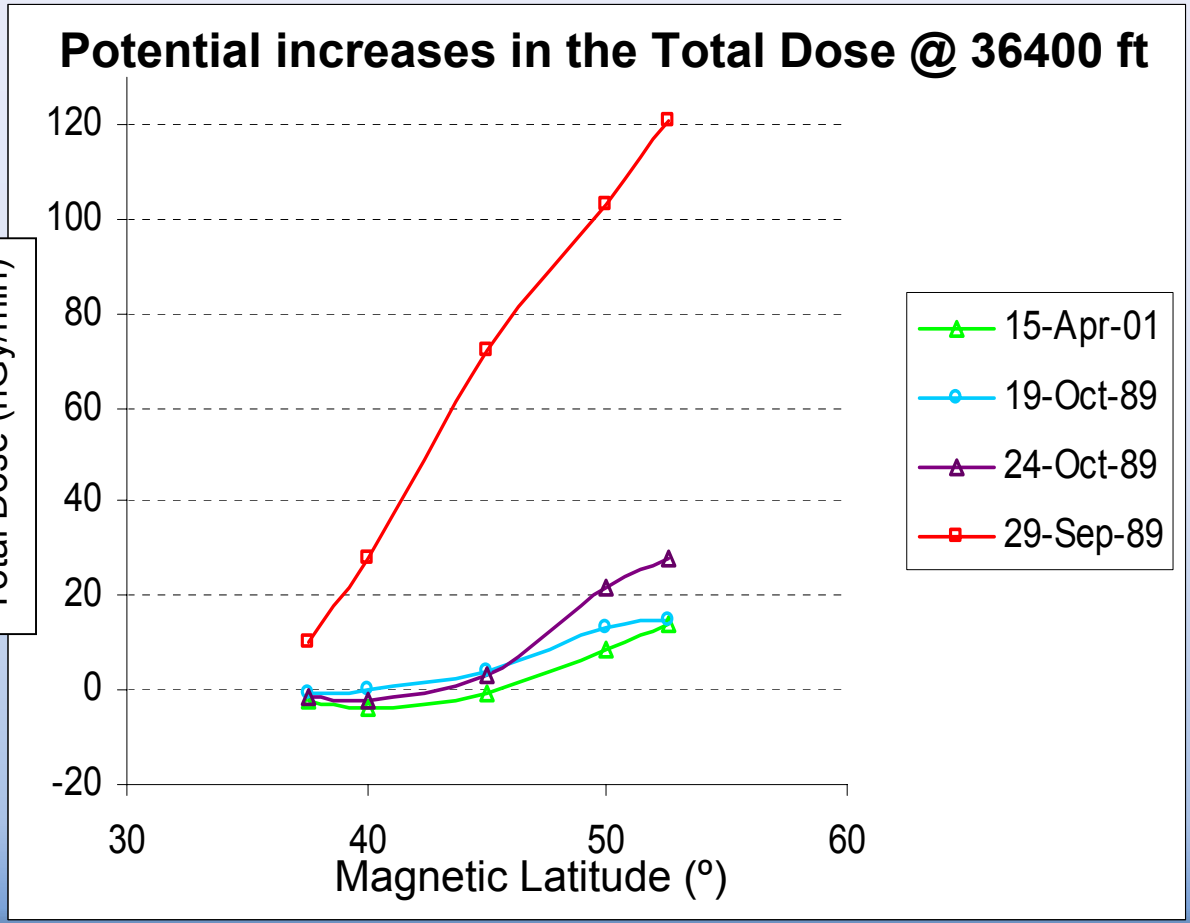
- The next step is to apply this to the Solar Comic Ray (SCR) enhancement
- For example, below are 4 cases of GLEs measured at cosmic ray ground stations



The resulting increase in the exposure rate @ 36400ft

However, this assumes that the Solar CR spectrum is the same as the GCR spectrum

1. The SCR spectrum is much softer, thus the result provides a best-case scenario only
2. The atmospheric SCR and GCR spectra are fairly consistent therefore it should be possible to determine a suitable scaling factor that will allow for the different spectra



Back-of-envelope calculation

An exposure of 8 hours during the 29-Sep-89 GLE at 36400ft (37°<MLat<52°) will result in an additional dose of 34 μGrays ≡ Eff. Dose ≈ 74 μSv

Equivalent to x1.6 the Eff. Dose received on a typical transatlantic flight

Conclusions

- Presented the effect of a CME driven Forbush Decrease on the Total Dose received at flight altitudes as a function of magnetic latitude
- Correlated the results of a Forbush Decrease on Total Dose with coincident world-wide GCR ground station monitors
- Determined an approximate 'best-case' scenario for estimating the effect of GLEs on the CR exposure at commercial flight altitudes

The results presented are for one case study, further research involving more cases will provide a better understanding and help constrain the parameters

In particular:

1. Further assess the relationship between the variation in Total Dose with GCR ground level measurements – does it deviate from linearity and if so what is the relationship
2. Identify the differences between the SCR and GCR spectra and how the propagation of SCR through the atmosphere differs

Difference in GCR intensity due to a Forbush Decrease

- Determined the difference in ground level GCR intensity for each pair of flights